

Non - arterial assessment of blood gas status in patients with chronic pulmonary disease

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SUMMARY

Assessment of blood gas status is important in the management of patients with chronic pulmonary disease. Arterial puncture is often painful and may damage the arterial wall. Measurement of oxygen saturation by transcutaneous oximetry offers a non-invasive alternative to arterial methods but does not allow assessment of partial pressure of carbon dioxide. We have examined the value of oximetry and dorsal hand venous carbon dioxide as an alternative to arterial puncture. Transcutaneous oxygen saturation correlated with arterial oxygen saturation ($r=0.76$, $p < 0.001$) with an error of 2.1% and dorsal hand venous carbon dioxide tension correlated with the arterial tension ($r=0.84$, $p < 0.001$) with an error of 8%. Changes in oximetric oxygen saturation and venous carbon dioxide tension following oxygen therapy reflected arterial values. Assessment of blood gas status using oximetry and dorsal hand venous carbon dioxide tension is a useful alternative to arterial puncture.

INTRODUCTION

The measurement of arterial blood gases in patients with chronic pulmonary disease is important in both diagnosis and management.¹ Arterial puncture is, however, a painful procedure and may occasionally damage the arterial wall.^{1, 2, 3, 4} It would be of benefit to patients if blood gas status could be assessed by less invasive methods, particularly if repeated measurement is required. Transcutaneous oximetry which measures oxygen saturation (SO₂) by the absorbance of two wave lengths of light is an accurate non-invasive method to assess oxygenation.^{5, 6} However, it is often important to know arterial carbon dioxide tension (PaCO₂), which reflects abnormalities of ventilation and this requires arterial puncture. In this study we have examined the reliability of assessment of blood gas status using ear oximetry for measurement of arterial oxygen saturation and dorsal hand venous partial pressure of carbon dioxide (PvCO₂) for estimation of arterial partial pressure of carbon dioxide.

METHODS

Forty-eight patients aged 62 ± 12 years (mean \pm SD) with chronic pulmonary disease (12 with pulmonary fibrosis and 36 with chronic obstructive lung disease)

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were studied in hospital during recovery from an acute exacerbation of their condition. Subjects sat comfortably for at least thirty minutes breathing room air connected to an ear oximeter (Biox II).^{5, 6} Simultaneous blood samples were taken anaerobically from the radial artery and from a dorsal hand vein and oxygen saturation was recorded from the ear oximeter (SeO₂). Both blood samples were analysed immediately for blood gases and pH. In 24 of the patients this procedure was repeated following the administration of oxygen via nasal spectacles at 21/min for one hour.

Arterial oxygen tension (PaO₂) was converted to saturation (SaO₂) using the method of Severinghaus which includes corrections for pH and PaCO₂.⁷ Values obtained from the different methods of measurement were then compared using a paired 't' test. The agreement between the variables methods was assessed by calculation of the coefficient of correlation by the least squares method and the error standard deviation and coefficient of variation (CV) as described by Bland.⁸

RESULTS

No significant difference was observed between the arterial and venous CO₂ tensions (PaCO₂ 41 ± 9.5 mmHg, PvCO₂ 42 ± 10.6 mmHg), and the two were closely related ($r = 0.84$, $p < 0.001$; Fig 1). The error standard deviation

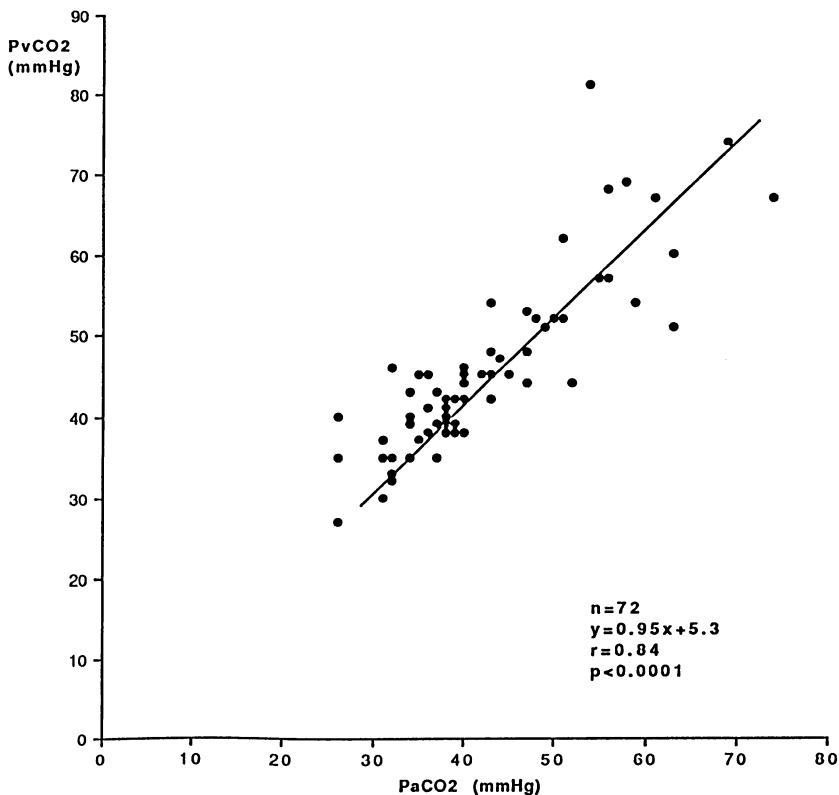


Fig 1. Relationship between dorsal hand venous (PvCO₂) and arterial (PaCO₂) tension of carbon dioxide. The line of regression is shown.

for PCO_2 was 3.5 mmHg and the coefficient of variation was 8% .⁸ No significant difference was observed between earlobe oxygen saturation (SaO_2 $93 \pm 5\%$, SeO_2 $94 \pm 5\%$, and the two were also closely related ($r=0.76$, $p<0.001$; Fig 2). The error standard deviation for SO_2 between methods was 2.1% and the coefficient of variation was 2.3% . Following the administration of oxygen ($n=24$) there was a significant increase in SaO_2 from $90 \pm 4.1\%$ to $95 \pm 2.7\%$ ($p<0.001$). A similar increase in SeO_2 from $92 \pm 5.1\%$ to $96 \pm 3.1\%$ ($p<0.001$) was also observed. Following O_2 therapy there was no significant change in PaCO_2 (39 ± 9 to 42 ± 9 mmHg) or PvCO_2 (40 ± 9 to 44 ± 10 mmHg).

DISCUSSION

Arterial blood gas determination, though the standard for assessment of hypoxia and hypercapnia, presents a number of difficulties. Arterial puncture is painful in over 25% of patients and causes bruising in 60% .³ The procedure may also be traumatic, resulting in direct arterial damage.^{4,9} In hypoxic patients it is sometimes difficult to determine if a sample is arterial or venous in origin and results may be discarded or considered to be misleading.

Transcutaneous oximetry is a simple and accurate method of assessing oxygenation in patients with compromised respiratory function. It is non-invasive and

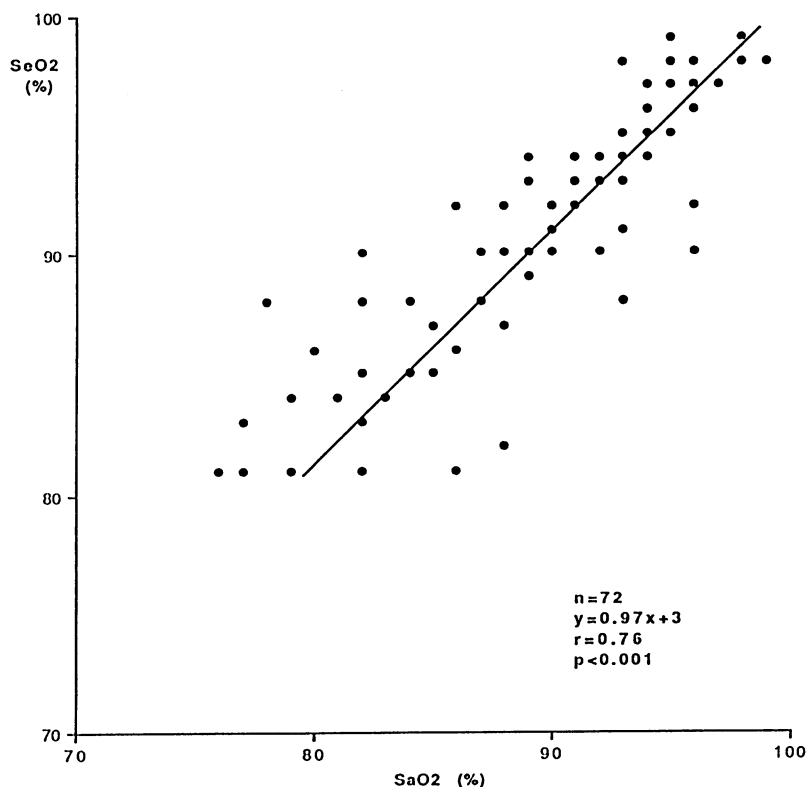


Fig 2. Relationship between ear oximetry (SeO_2) and arterial blood gas (SaO_2) estimations of oxygen saturation. The line of regression is shown.

allows continuous monitoring of oxygen saturation, but provides no information regarding carbon dioxide tension. In conditions where hypoventilation or ventilation : perfusion mismatching occur, hypercapnoea may develop following oxygen therapy. This is potentially dangerous as carbon dioxide narcosis will further reduce respiratory drive and may result in coma and death.¹⁰ It is therefore important to monitor carbon dioxide levels in such patients and this usually requires arterial puncture.

We have shown good agreement between direct arterial measurement of oxygen saturation and saturation determined by ear oximetry, confirming the utility of this non-invasive method.^{5, 6} The coefficient of variation of the measurements is small and in general within the variability of the machine.⁶ Similarly, there was good agreement between PaCO₂ and PvCO₂ in blood from a dorsal hand vein. When dorsal hand venous blood is arterialised using a hand warming device, gas tensions are similar to arterial blood.¹¹ Many patients with chronic pulmonary disease have carbon dioxide retention, and are already vasodilated, so no arterialisation procedure need be undertaken. The coefficient of variation for the difference between methods is within the assay variation for PaCO₂, (4–12%).¹² Oximetric measurement of saturation tended to underestimate blood gas values by 3%, and venous assessment of PCO₂ overestimated by 5 mmHg. However, both methods were accurate in detecting changes following oxygen therapy when the error for PCO₂ was 2.3% and PaO₂ was 5%.

In conclusion we have shown good agreement between venous and arterial measurement of CO₂ tension, and between arterial and oximetric measurement of O₂ saturation. Venous blood sampling and ear oximetry are less invasive than direct arterial puncture, and the information obtained accurately reflects blood gas status. These relatively simple investigations should be of value when monitoring patients with chronic pulmonary disease.

REFERENCES

1. Fraser RG, Pare JAP. Measurement of blood gases and H⁺ ion concentration. In: Fraser RG, Pare JAP, Pare PD, Fraser RS, Genereux GP, eds. *Diagnosis of diseases of the chest*, 3rd edition. Philadelphia: W B Saunders, 1989: 335.
2. Cole P, Lumbley J. Arterial puncture. *Br Med J* 1966; **i**: 1277-8.
3. Capewell S, Ali N, Makker H, et al. Radial artery puncture: a comparison of three haemostatic techniques. *Resp Med* 1990; **84**: 495-8.
4. Williams T, Shenken JR. Radial artery puncture and the Allen test. *Ann Int Med* 1987; **106**: 164-5.
5. Tweeddale PM, Douglas NJ. Evaluation of the Biox IIa ear oximeter. *Thorax* 1985; **40**: 825-7.
6. Chaudhary BA, Burki NK. Ear oximetry in clinic practice. *Am Rev Respir Dis* 1987; **117**: 173-5.
7. Severinghaus JW. Blood gas calculator. *J Appl Physiol* 1966; **21**: 1108-16.
8. Bland M. *An introduction to medical statistics*. Oxford: Oxford University Press, 1987.
9. Sabin S, Taylor JR, Kaplan AL. Clinical experience using a small-gauge needle for arterial puncture. *Chest* 1976; **69**: 437-9.
10. Kryger MH. Respiratory Failure 2: carbon dioxide. In: Kryger MH, ed. *Respiratory Medicine*, 2nd edition. New York: Churchill Livingstone, 1990: 211-26.
11. Forster HV, Dempsey JA, Thompson J, Vidrak F, doPico GA. Estimation of arterial PO₂, PCO₂, pH and lactate from arterialised venous blood. *J Appl Physiol* 1972; **32**: 134-7.
12. Burki NK. Arterial blood gas measurement. *Chest* 1985; **88**: 3-4.